Study on Sea Surface Temperature Front Disappearance in the Subtropical North Pacific

著者	邱 春カ
number	56
学位授与機関	Tohoku University
学位授与番号	理博第2720号
URL	http://hdl.handle.net/10097/56906

氏名・(本籍)	邱(きゅう) 春(しゅん) 华(か)
学位の種類	博　士(理　学)
学位記番号	理博第２７２０号
学位授与年月日	平成24年9月25日
学位授与の要件	学位規則第4条第1項該当
研究科，専攻	東北大学大学院理学研究科（博士課程）地球物理学専攻
学位論文題目	Study on Sea Surface Temperature Front Disappearance in the Subtropical North Pacific (北太平洋亜熱帯域における海面水温フロント消滅に関する研究)
論文審査委員	(主査) 教授 川村　宏 教授 岩崎俊樹 教授 須賀利雄 准教授 木津昭一 准教授 境田太樹

論文目次

論 文 内 容 要 旨

The subtropical front is a major structure in the North Pacific. There are two kinds of thermal fronts in the subtropical area. One is the subsurface front, which is stable throughout the year and associated with the subtropical countercurrent. The other is the surface (or SST) front. It has significant seasonal variations, with strong gradient magnitude (GM) in winter and weak GM in summer. The seasonal variation of the SST front is related to air-sea interaction. The subtropical SST front in winter has been studied by many researchers; however, few studies have been conducted for its weakening process, which is attributed that the SST front has high variability during spring-summer. The weakening process and the disappearance of the subtropical SST front during the heating season are the subject of this thesis.

For investigating the subtropical SST front, in situ observations have been traditionally used, but their temporal/spatial coverage is sparse. In contrast, recent satellite observations have wider coverage and higher temporal/spatial resolutions. Since around 1980, SSTs observed by infrared radiometers have been employed for studies of the subtropical SST front. However, the SST data measured by infrared radiometer are easily contaminated by clouds, especially in the subtropical front area. Since microwaves emitted from the sea surface carry information of the SST through clouds, the microwave radiometer measures SST under clouds. As

mentioned above, the area of the subtropical SST front is frequently covered by clouds, and the front has high variability because of the strong coupling with the air-sea interaction. Therefore, the microwave radiometer is a feasible tool for this study.

The purposes of this study are 1) to investigate the weakening and disappearance process of the subtropical SST front during spring-summer using the cloud-free SST of Advanced Microwave Scanning Radiometer for the Earth Observing System (AMSR-E), and 2) to examine the mechanisms of the SST front weakening and disappearance based on a mixed layer model, taking advantages of the AMSR-E SST, the in situ data and the reanalysis data. In Section 1, the backgrounds of this thesis are presented.

In Section 2, data and methods are described in detail. The study period is from April to September for 2003-2009, and the study area is the western North Pacific (20-32°N, 135-150°E). The cloud-free AMSR-E has high temporal/spatial resolutions of day/0.125°, which has not been used for research of the subtropical SST front. The vertical structure of the subtropical front is investigated using Global Temperature-Salinity Profile Program (GTSPP) data. In addition, National Centers for Environmental Prediction /National Center for Atmospheric Research (NCEP/NCAR) reanalysis surface heat flux and wind speed products are introduced. Two detection methods of the SST front are employed; 1) gradient magnitude (GM) and 2) edge-detection using Jensen-Shannon divergence filter (JSD).

In Section 3, the SST front weakening and disappearance are carefully investigated by 7-year daily/0.125° AMSR-E SST. In April, the SST fronts are strong with a high GM and JSD bands; in August, SST becomes high and uniform, with small GM (<0.8℃/100 km) and JSD (<0.75). Since the SST front bands become invisible in GM/JSD snapshots and weekly to monthly averaged images, this phenomenon is called 'SST front disappearance (SFD)' in this study. Monthly histograms of the SST show that the SST front weakens in May-August. The SST increases much quicker in the north than that in the south of the SST front. In June and July, the SST front is unstable with quite large GM deviations.

For the period of the SST front weakening and disappearance, thermal structures of the upper 200 m layer are investigated using the GTSPP data. It is confirmed that, when the SFD occurs, the subsurface subtropical front is stable. The weakening of the SST front mainly influences the upper 50 m depth, and it is suggested to be related to the mixed layer dynamics.

In Section 4, the SFD mechanisms are examined using the 2.5° weekly match-up datasets of the AMSR-E SST/GM, the NCEP/NCAR net surface heat flux/wind speed and the GTSPP mixed layer depth (MLD). The employed mixed layer model estimates the SST and GM variations through 1) the air-sea net heat flux and the downward shortwave radiation at the bottom of the mixed layer, 2) the oceanic Ekman advection, and 3) the entrainment at the bottom of the mixed layer. The quantitative analyses using this model support that the air-sea net heat flux rather than the Ekman advection and the entrainment primarily controls the SST front weakening process and SFD.

It is found that the model results from the weekly match-up datasets and the monthly match-up datasets are different. The former agrees well with the AMSR-E observations, but the latter has a large difference with the AMSR-E measurements. It indicates that the weekly or much shorter-time observations are necessary to examine the SFD mechanisms.

Decomposition analyses of the net heat flux, being comprised of net shortwave radiation, net longwave radiation, sensible heat flux and latent heat flux, reveal that the latent heat flux dominates the SST front weakening; the shortwave radiation contributes to establish the shallow mixed layer enhancing the SST front weakening. The southerly wind prevails across the SST front zone during the SST front weakening process. It transports the high humidity air mass crossing the SST front, and then the humidity difference becomes smaller in the cold zone north of the SST front. Thus, the ocean releases less latent heat, leading to a larger SST increase in the north of the SST front. Finally, the large (small) SST rise in the cold (warm) zone north (south) of the SST front results in the SFD.

In Section 5, the conclusions and future plans are presented. Throughout this study, the SST front weakening processes are revealed by the daily/0.125° AMSR-E SST. The mechanisms of SST front weakening are also well examined by weekly match-up datasets and the employed mixed layer model. The SFD in other areas and the smaller-scale variations of the SFD deserve future study.

論文審査の結果の要旨

亜熱帯フロントは北太平洋の主要な海洋構造の一つであり、下層フロントと海面水温(SST)フロントから構成されている。冬季、大きなSST水平勾配(GM)が出現するが、夏季には消えてしまう。春季から夏季にかけて、GM強度が弱化し、SSTフロントが見えなくなってしまう現象を「SSTフロント消滅(SFD)」と名付けた。本研究の特徴は、1）雲に影響されず、高い時空間分解能と広い観測幅を有するマイクロ波放射計の7年間のSSTデータをはじめて使用したこと、2）それに加え、現場観測、再解析データを用いて、混合層モデルによってSSTフロント弱化・消滅メカニズムを明らかにしたこと、である。

4月、亜熱帯域のGM強度は大きいが、8月にはGM = 0.8℃/100km以下となる(SFD)。5-8月に、フロント北側の水温が南側に比べて急速に上昇することでSSTフロント弱化が進行する。6-7月は、GMの変動幅が大きくなり、SSTフロントは不安定である。SSTフロント弱化期間の表層200mの温度構造を水温・塩分鉛直分布を用いて調べた。SFDが起こっていても下層フロントは安定して存在する。SFDは表層50mまでに影響を与えるだけであり、混合層と深い関係がある。

2.5度格子のSST、GM、再解析熱フラックス・風速、混合層深度を週毎に組み合わせ、データセットを作成した。混合層モデルにより、SSTとGM変動を、次の3つの効果を考慮して解析した；1）正味の海面熱フラックスと混合層下部における下向き短波放射、2）海洋のエクマン輸送、3）混合層下部におけるエントレインメント。週毎データセットを用いた混合層モデルの結果は、SSTとGMの観測事実とよく整合する。月毎データセットを用いた結果は、週毎データセットを用いた結果と大きく異なる。SFDメカニズムの解明にあたっては、週毎かそれより短い解像度を持つ観測データが必要である。

熱フラックスの効果を詳細に解析したところ、潜熱フラックスがSSTフロント弱化にもっとも貢献していることが分かった。南よりの風が卓越し、SSTフロント域を横切って吹くとき、フロント弱化が加速する。つまり、南風が運ぶ湿度の高い空気塊がフロント北部の低SST海域にもたらされると、潜熱放出が押さえられ、SSTが急速に上昇していく。それにより、高SSTで昇温の小さい南側とのSST差が小さくなり、SFDが発現する。

この研究により、亜熱帯域のSSTフロント消滅の実態が明らかとなり、その発生機構が解明された。これは、自立して研究活動を行うに必要な高度の研究能力と学識を有することを示している。したがって、邱春华提出の博士論文は、博士（理学）の学位論文として合格と認める。